AUGUST 15, 1920

AVIATION AND AERONAUTICAL ENGINEERING

VOL. IX. NO. 2

Member of the Audit Bureau of Circulations

INDEX TO CONTENTS

THE GARDNER, MOFFAT COMPANY, Inc., *Publishers*

HIGHLAND, N. Y.

HARTFORD BUILDING, UNION SQUARE, 22 EAST SEVENTEENTH STREET, NEW YORK

SUBSCRIPTION PRICE: THREE DOLLARS PER YEAR. SINGLE COPIES TWENTY-FIVE CENTS. CANADA, THREE AND A HALF DOLLARS. FOREIGN, FOUR DOLLARS A YEAR COPYRIGHT 1920, BY THE GARDNER, MOFFAT COMPANY, INC.

ISSUED ON THE FIRST AND FIFTEENTH OF EACH MONTH. FORMS CLOSE FIVE DAYS PREVIOUSLY. ENTERED AS SECOND-CLASS MATTER MAY 19, 1920, AT THE POST OFFICE AT HIGHLAND, N. Y., UNDER ACT OF MARCH 3, 1897.

L. D. GARDNER
PRESIDENT AND EDITOR
W. D. MOFFAT
VICE PRESIDENT
W. I. SEAMAN
TREASURER
H. M. WILLIAMS
GENERAL MANAGER

AVIATION AND AERONAUTICAL ENGINEERING

ALEXANDER KLEMIN
TECHNICAL EDITOR
LADISLAS d'ORCY
ASSOCIATE EDITOR
GEORGE NEWBOLD
BUSINESS MANAGER

Vol IX AUGUST 15, 1920 No 2

IS it not time there was a system of licensing aircraft in use in America? Now that the wartime ban is off civil flying there is nothing to prevent a person from putting his own and a number of other people's lives and property in uncalled-for danger.

Driving an automobile is admitted to be far easier than flying, yet no steps are taken by the state to make sure that a flier is competent before he is allowed to take a machine into the air, while it is the universal practice that certain requirements must be fulfilled in order that a person may be permitted to drive a car. The skill and intelligence requisite in the two cases are not at all comparable, and the potential damage which can be done in the event of loss of control is also greater in the case of aircraft.

As at present constructed airplanes and airships are rapidly becoming as reliable vehicles as other automotive machines for transportation are. The conclusion is therefore reached that some sort of supervision should be maintained over aircraft by the state.

There are a number of ways in which control could be maintained. In the first place the machine should be structurally safe. In the early days of flying with the low-powered motors then available the quality of lightness was paramount in the structure. Very little structural engineering was applied to the designs and many weak structures and the inevitable crashes resulted. Today we take pride in our ability to determine the strength of an airplane with but a slight degree of uncertainty, and instances of the structural failure of aircraft designed by a competent aeronautical engineer are rare. There should therefore be no difficulty in keeping this type of accident down to a negligible quantity.

Stability and controlability are also well understood by the engineer and with proper precautions this source of danger may also be eliminated.

The remaining difficulty and the one which causes most of the crashes today is the failure of the power plant. The complexity and the high duty demanded of an aeronautical power plant both detract from its reliability but they are unavoidable to a large degree. However, much can be done in the way of requiring approval of gasoline and cooling systems and motors.

In the event that the government refuses to take these or steps to the same effect—namely to protect purchasers, passengers and the man on the ground alike—it is to be feared that unsound developments will result in a skeptical and even hostile attitude on the part of the general public toward aviation. The point is already being brought up in connection with aircraft insurance and we may hope for a correct solution of the problem by the insurance companies in the establishment of something analogous to the National Board of Underwriters.

Constant Torque

Many attempts have been made to maintain constant torque in an aeronautical internal combustion engine at altitudes. Most of the methods tried fall into one or the other of two classes. The first, supercharging, has been developed to a point where there is a certain measure of success in sight although the added mechanism is somewhat heavier and more unreliable than desirable.

The other is to increase the compression ratio at ground level beyond the value which will give best operating characteristics at that altitude. The compression will then fall at greater altitudes and operation will improve until the best ratio is reached at the height for which the motor is designed. A corresponding gain in power will then be shown over a motor with the same displacement but lower compression. A modification of this method which shows a still greater improvement in power at altitudes is to vary the compression ratio with the altitude by changing the length of stroke. Using this principle the optimum compression ratio can be obtained at all heights within limits imposed by the mechanical features of the device. A second result is the increase in displacement with stroke, which of course augments the charge.

With the latter method, the gain in power over the ordinary engine at 15,000 ft. is four times that obtainable with a constant compression motor of optimum compression. The weight of the stroke changing device is only 5 per cent of the engine weight, while the gain in power by its addition is 50 per cent, which is very much worth while.

Helpfulness of the Wright Lecture

The Wilbur Wright Lecture by Commander Hunsaker will do much toward simplifying and crystallizing the design of the airplane in many important particulars. The appendices to the lecture are a mine of information into which designers may delve with great benefit. The analysis of the data there presented is very well carried out, and the conclusions drawn carry more weight than generalizations arrived at from a theoretical standpoint alone. In fact a common sense attitude is maintained throughout the paper.

In the introduction of the conception of metacentric height to airplane model tests, a very useful method for interpreting and analyzing the vector motion effect on stability has been clearly explained. Much has been written on this subject but little has been stated in a form so lucid to the engineer as by the use of metacenters.

Control surface areas are successfully designed by empirical coefficients, and a mass of data on this important subject has been put in a form of great value to the designer. It is rather interesting to note the slow advance in this particular branch of aeronautics. Refinements of the method rather than an advance in theory mark the progress.

Although there has been only a moderate amount of airship construction carried out in this country, it is pleasing to note from the technical literature of the day that there is a live interest being shown here in this branch of aeronautics. Those who may have apprehensions that we are not following the development of this type of craft may take some comfort from the attention given to the subject by Commander Hunsaker.

Determination of the Resistance of Airship Models

By R. H. Smith

Wind Tunnel, U. S. Navy Yard, Washington, D. C.

Much of the early experimental work of consequence on the head resistance of airship models has been done on one or the other of two standard types of aerodynamic balances, the Eiffel or the bell-crank type. The Eiffel balance is of French origin and takes its name from the celebrated French experimenter, while the bell-crank type is probably of American origin, being used in this country since early in 1901.

The bell-crank type is the more familiar of the two to American investigators, most of our balances being of this type. This is largely due to its directness and simplicity, which especially commend it as equipment for smaller wind tunnels. In fact almost all wind tunnels under 20 sq. ft. section, and many of larger section—such as the 7-ft. tunnel of the Curtiss Engineering Corp., at Garden City—are equipped with the bell-crank type balance.

The outstanding example in America of the Eiffel balance is the three-moment balance which is mounted in our largest wind tunnel, the 64 sq. ft. section tunnel at the Navy Yard, Washington, D. C.

It would be well, therefore, in a discussion of wind tunnel tests on airship resistance to compare these two types as to their theory and subsequent design, and especially as to their merits for this class of work.

The Bell-Crank Type

The theory upon which the bell-crank types are designed to function is expressed in the simple equation

$$F = M/r$$

where F is the force to be determined, the resistance of an airship model for instance, M the moment which this force produces about any axis in a plane perpendicular to the force, and r its moment arm. Since the two principal forces that an aerodynamic balance is required to measure are lift and drag, which act across and with the wind respectively, the bell-crank types have two principal moment arms, one parallel to and the other perpendicular to the airstream.

For simplicity in operation and design these balances are invariably made with the two moment arms intersecting at their mid points, and with their moment axes in the same plane. A drag or resistance force would therefore be determined from the moment it produced about the axis across the wind and from the distance from the knife edge plane to the line of action of the force. Since this moment arm must be known, the use of bell-crank types of balances is theoretically limited to those models which have a plane of symmetry parallel to the wind because only for such models can this distance be made known. In practice, however, the limitation disappears because all models have such a plane and can be mounted so that this plane is parallel to the plane of the moment axes.

The precision of a force determination on one of these balances is approximately the same as the precision of the moment from which the force is obtained. The error in r can be made so small that it may be neglected. Therefore in order to measure a force such as the resistance of an airship model for instance precisely to a thousandth part of a pound, the balance must be dynamically sensitive to a change in the moment of r thousandths of an inch pound. This is near the limit of precision of even the more modern designs.

The Eiffel Balance

The Eiffel types, on the other hand, are designed to make use of the equation

$$F = \frac{M_a - M_b}{l}$$

in which M_a and M_b are two independent moments which the force F produces about two parallel axes a and b, which are a distance l apart and in the same plane perpendicular to the force. It is obvious that with the Eiffel balance the magnitude of the force can thus be determined independent of its location giving, therefore, a more general solution of F than that given by the bell-crank.

Although Eiffel used a two-moment balance, mounting the model first normally then inverted, the design of the Eiffel balances usually takes the general form of three moment axes arranged in the figure of a right triangle. Two axes, about which moments are taken for the determination of drag or resistance, are set in a plane, perpendicular to the true airstream, and two in a plane parallel to the true airstream for a similar determination of lift. The distances l between the axes corresponding to the two legs of the triangle are accurately known constants of the balance.

For accurate measurement of drag forces this type of balance, when used normally, is at a decided disadvantage due to the serious loss of precision in taking the difference between quantities of about the same magnitude. If the ratio of the arms from the two drag moment axes to the model is about 5 to 6, which are average values, the percentage error in the difference of the moments, and consequently in the force, is about three times the percentage error in either moment alone. For this reason in measuring the resistance of airship models, the Eiffel balance is often used as a single moment balance and the arm measured from the moment axis to the point of application of the force. When used in this way, the Eiffel balance virtually becomes bell-crank and gives about the same precision.

The most serious difficulty, however, in the use of wind tunnel balances for airship resistance work lies not so much in their inherent precision, or lack of it, as in the problem of correcting accurately for the double influence of the exposed spindle by which the model is attached. The usual correction made in tests on airplanes and other models where the resistance is due principally to so-called "form" resistance, is a single correction for the windage on the exposed spindle, care always being taken to keep the wind flow about the spindle the same as that during the test by detaching but not removing the model. For airship envelopes and other streamline forms, however, where the resistance is due primarily to skin or surface friction—80 per cent or more of the total resistance of a good streamline form being due to skin friction—a second correction becomes necessary to allow for the breaking up of the surface flow in the wake of the spindle. This correction must be measured independent of the windage correction and in practice is found difficult to determine.

In order to reduce these correction difficulties, especially with the view of avoiding unnecessary disturbance of the surface flow, another method has been used for mounting and supporting the model. The model is suspended by means of fine wires in such a position upstream from the balance as will permit its attachment to the balance beam by a reasonably long horizontal compression pin running from model stern. Although two corrections are still necessary, requiring two independent correction tests, both lend themselves to accurate determination. That part of the total resistance due to the exposed spindle and compression pin can easily be determined in the usual way with the detached model held in position. A very satisfactory method for correcting for the exposed wires is discussed below in connection with the bifilar balance.

It should be pointed out in the use of this method that the suspension wires must be of sufficient length to render negligible any component which they may have along the stream due to slight horizontal movement of the model. This precaution carries weight when the fact is considered that the up and down stream motion of the spindle of an average bell-crank balance is at least twice the swing of the index at the end of the weight beam by which accurate balancing is secured. If the scale over which the index swings is read with the naked eye the precision of the index setting may be taken as 0.01 in. It follows that the up and down stream position of the model is uncertain to at least 0.02 in. If the resistance of the model is desired to thousandths of a pound, it is obvious that the ratio of the length of the suspension wires to the weight they carry, which is approximately the weight of the model, must be about 20 to 1. An average 30 in. solid

wood model will weigh about 20 lb. The suspension wires to such models should therefore be about 30 ft. long. Too often, in the use of this method, the wires supporting the model have been suspended from the tunnel ceiling, a distance of 3 ft. or less above the model.

As a result the difficulty of properly suspending the models becomes almost as serious as the difficulty of correcting for the influence of the spindle on the model when attached in the usual way, a small gain for the complications it makes necessary in the apparatus.

The Bifilar Balance

These difficulties coupled with the need of better precision have lead to the development of the wire suspension apparatus called the Bifilar Balance. This apparatus consists essentially of two steel wires running parallel from a considerable height down through the tunnel ceiling and attached to the model located about midstream. A long steel pin at each end of the model loosely engages a streamlined slip-ring fastened to a horizontal taut crossstream stay wire, preventing yawing and pitching oscillations, but allowing free longitudinal motion. As much of the suspension wires in the stream as possible is shielded from the wind. At a convenient place just above the tunnel ceiling a light beam spanning the wires carries a needle point across a scale graduated in hundredths of an inch and on which, with the aid of a magnifying glass, the displacements of the model are read for the different wind velocities.

For testing models whose resistance is large in proportion to their weight, an iron deadweight frame, carrying as many smaller weights as the test may require, is suspended in the system inside the windshield to reduce the displacement to convenient magnitude, the model being suspended from the bottom of the frame and guyed in the usual way. For use in testing the resistance of struts, and other irregular models which have a longitudinal plane of symmetry, this weight frame is provided with a sturdy prow pin to serve as a horizontal spindle attachment as well as a lateral guide in the shield.

The equation upon which the use of this apparatus rests is $R = Kd$ where R is the resistance in lb. and d the displacement of the pointer in the scale in in.

The magnitude of the resistance is thus directly proportional to the displacement measured at the scale, independent of the distribution of either the resistance or the weight below the scale.

In tests on airship envelopes no deadweight is necessary. For such tests, therefore, the formula becomes simply

$$R = \frac{W}{l}\, d$$

where W is the weight of the model in lb. and l the distance from the points of suspension to the plane of the scale. Proper account should be taken of the weight of the wires, the beam carrying the index point and any other weights that may enter to increase the weight in the system.

Convenient displacements in testing airship envelope forms are obtained if l in in. is made about ten times the weight of the average model in lb.

The proper distance to suspend the model below the windshield can be easily determined by measuring at some convenient velocity, the scale displacements of an average airship model suspended at successive distances below the shield. By plotting the displacements against distances the position at which the curve breaks from a straight line can be easily read. At this point the resistance of the model and wires no longer reduces proportionately to the length of wire exposed, indicating interference from the shield at that position. The distance used should be 10 or 15 per cent more than the minimum distance found.

Wire Correction

While the bifilar balance does not eliminate the spindle correction problem, it greatly reduces its difficulties by lending itself to very accurate wire correction determinations. The method is as follows: a stub wire, of the same diameter as the suspension wire is run from the model parallel to and at the side of each suspension wire up into the shield where it terminates in a small slip attaching it to the suspension wire. The wires should be spaced about ten diameters to eliminate interference. The scale displacements are found at the various wind velocities with these four wires exposed. The two stub wires are then removed and with the two remaining wires exposed the test repeated. If the difference in the displacements found are taken from the displacements when two wires are exposed the displacements are obtained for the model with no wires attached.

Data on wire resistance obtained in this way is obviously of no value in itself because for a well mounted model, the resistance of practically the full length of exposed wire is affected by the model and by each model differently. Probably the most striking discrepancy in the data, incidentally, is in the wide variation in the exponent of the velocity with which the wire resistance seems to vary.

Pressure Gradient Correction

In addition to the wire or spindle corrections it has recently been found necessary to apply a correction for the buoyancy produced by a fall of static pressure down stream, a condition found in all tunnels of more or less uniform section. Only within the last year has this disturbing phenomenon attracted the attention of experimenters in this country.

This static pressure gradient correction is of considerable relative magnitude only on such streamline forms as airship envelopes, whose volumes are quite large compared to their resistances. On aerofoils at their minimum drag incidence this pressure gradient correction is probably in no case more than 0.2 per cent of the drag and on airplane models is much less. On airship envelopes the gradient correction is likely to be as much as ten per cent of the resistance.

After the pressure gradients have been found for the tunnel unobstructed by this model the general method of determining the gradient correction on a model is to integrate the static pressure over its surface. The integral form is

$$P = \pi \int p \, d(r)^2$$

where p is the static pressure and r the envelope radius at any station along the model axis and P is the pressure gradient correction in lb. Excepting in special cases such as mathematical forms in air streams of constant gradients where p as a function of r is known, this integral is mathematically indeterminate. In practice the integration is affected by plotting a graph of the static pressure in proper units as abscissa against r^2 as ordinates for each station chosen along the axis of the model and planimetering for the area. Ten well chosen points will be found to give sufficient precision for correction purposes.

It does not follow that with the pressure gradient correction for one wind velocity known the corrections for any other can be computed, except, as will be explained later, in the special case in which the static pressures for all points along that part of the tunnel used, varies at some constant power of the wind velocity. It may be found that the static pressure at no two points varies at the same power of the velocity and all may vary at a higher power than the square. In general the lower the static pressure, that is, the further down stream the point, the higher will be found the power of V to which the pressure at that point varies.

In the general case therefore in which the tunnel gradients are variables and the static pressures at successive points down stream vary at different powers of V, the pressure gradient must be accurately determined for each velocity and a separate integration made for each correction. This is obviously no enviable task.

If, however, in a tunnel of variable gradients, the static pressures at successive points down stream vary at some constant power of V, that is V^n, then the correction found from a single integration may be converted into a correction for any velocity by the formula

$$P = K V^n$$

where P is the correction in lb at the velocity V chosen.

In practice it may often be found that the pressure gradients for the part of the tunnel occupied by the model are constant for all velocities. In those laboratories which have tunnels whose gradients are constant, regardless of the power of V at which the static pressure varies at successive points down stream, the matter of determining the static pressure gradient correction is radically simplified. Archimedes' principle then applies and it becomes a matter of multiplying into the volume of the model, as given by the designers, a constant,—the rate of static pressure drop downstream—for each speed for which correction is desired.

The determination of these constants is quite simple. It is most easily done by drawing on logarithmic paper, with ordinates marked for lb. per sq ft. static pressure and abscissa marked for velocity, the two straight lines giving the variation of the static pressure with velocity for the two extreme points inclosing the up and down stream range desired. By taking the difference between the curves for any desired velocity and dividing by the distance between the stations (in ft.) the rate of static pressure drop is obtained in lb. per sq. ft. per ft. These buoyancy constants in lb per cu. ft. units can thus be obtained for all velocities and preserved as permanent calibration constants of the tunnel

The method for correcting for constant pressure gradients has recently been developed and used at the wind tunnel of the Washington Navy Yard, where the gradients were found to be constant over the length of the tunnel occupied by the model

Because static pressure calibrations are made when the airstream is unobstructed by the model, it may appear to the reader that the distortion of the gradient due to the presence of the model in the channel renders the preceding discussion invalid. It will only be necessary to suggest that the distorted gradient is a part of the model resistance and that so long as the tunnel section is large enough to allow the air stream to function about the model as an infinite stream—a question always to be predetermined— the condition is the normal flying condition of the full sized craft. The only difference being that the model distorts a gradient of some finite slope while the full sized craft in the open air distorts in a similar way a gradient of approximately zero slope.

In academic interests it might be well to note that the fall in static pressure down stream affects a slight change in the ρ and V terms of the resistance equation

$$R = \rho A V^2 f\left(\frac{VL}{\nu}\right)$$

causing ρ to decrease and V to increase To illustrate concretely, assume an actual case in which the static pressure drop, in a tunnel of constant gradients, is at the rate of 0.01000 lb per sq. ft. per ft. at 30 m p.h This is equal to approximately a 0.0005 per cent drop in the absolute pressure for each foot length of tunnel By Boyles Law there is a simultaneous and equal percentage reduction in ρ and increase in V for the same length of tunnel This gives by inspection, since

$$\frac{dR}{R} = \frac{d\rho}{\rho} + 2\frac{dV}{V}$$

a positive error in R due to neglecting the variation of ρ and V, of approximately 0.0005 per cent for each foot the model is distant from the position of the Pitot tube or static plate at which the velocities for the test are determined This is true regardless of the position of the point along the stream at which the pressure gradient and atmospheric lines intersect The error of course is at most far too small for consideration

Precision

A complete precision discussion of the results obtained by the bifilar balance would necessarily include a more or less wide range of questions not strictly bearing upon the apparatus. Strictly speaking, however, the precision of the balance is solved by the equation

$$\frac{dR}{R} = \frac{dW}{W} - \frac{dl}{l} + \frac{dd}{d}$$

which follows from the equation

$$R = \left(\frac{W}{l}\right)d$$

It is always a simple matter to determine W to 0.1 per cent. The value of l, being a constant of the apparatus, can be determined to any precision desired; assume it to be correct to 0.05 per cent. The accurate determination of d is more difficult, the precision depending largely on the uniformity of the wind velocity By taking the average of a number of observations, however, each of which is taken when the wind velocity is as nearly correct as possible, the error in d at low velocities, that is 20 m.p h, should not be more than 0.5 per cent and decreasing for higher velocities and larger displacements. Consequently the largest error in R due to the inaccuracy in determining W and l and in reading d is about 0.7 per cent at 20 m.p.h. At 70 m.p.h. it should not be more than 0.4 per cent.

The other questions which enter into the overall precision of the results of the bifilar balance are questions more or less common to all other types of tunnel balances and comprise, for the most part, the precision of the various tunnel calibrations.

The direction of the air stream in the vertical plane must be accurately known in order that the model may be set at zero incidence. Although the rate at which the resistance varies with a small change of the wind incidence from zero is very small compared to the rate of change of the lift, the percentage increase in the resistance due to the small incidence is twenty or more times the percentage error resulting from the lift changing the resultant weight of the model. An incidence of 0.25 deg on an average solid wood model will cause a 0.4 per cent increase in the resistance and an error in the measurement of the resistance of less than 0.02 per cent, due to the effect of the lift on the model weight.

Therefore, neglecting the lift on the model, the direction of the wind should be known to 0.25 deg to keep the precision of the mounting consistently within the precision of the test.

Another question that arises is how precisely the velocities as read on the manometer are the true effective velocities producing the model displacements. The precision of this agreement depends first upon the accuracy of the velocity calibration for that part of the tunnel section affecting the model, and then upon the accuracy of whatever calibration may be necessary in any particular case, to compensate for the difference between the mean effective velocity found and the velocity found at the position of the Pitot tube from which the velocities for the tests are determined.

If the wind velocities are obtained by a Pitot tube mounted on the windshield for convenience, corrections for the effect of the shield on the Pitot must be determined and accounted for in the calibration.

In order to check the last two corrections it will be found advisable to mount one Pitot tube at that point in the affected area which is nearest the mean effective velocity and another in the position of the Pitot tube in the regular testing and by connecting each to a calibrated manometer determine directly what the readings of the regular speed Pitot should be to give correct velocities at the test position.

It is not difficult to do this calibration work with such accuracy that the total precision is well within the precision of a manometer reading when the meniscus is fluctuating. The accuracy to which the velocity at the test position is known may therefore be regarded as the precision to which the manometer can be read Since the uniformity of the velocity, which determines almost entirely the meniscus fluctuation, is different for different tunnels, the precision to which the velocity is known becomes a function, in each particular case, of the character of the tunnel, and in a precision discussion is an unknown which each laboratory must determine for itself

The effect of the wire correction and pressure gradient correction on the precision of the bifilar balance data is in both cases negligible. While, in the case of the wire correction, the displacement values for the model with no wires attached are theoretically, value for value, less than one third as precise as the displacement values for the model with two or four wires attached, in practice they are made equally or more precise by faring out the errors in the test values and subtracting the faired differences. The legitimacy of faring is based upon the long known fact that the resistance of streamline forms varies as a single function of the velocity for the normal experimental velocity range. Consequently the resistance equation can be expressed in a simple linear logarithmic equation which, when plotted on logarithmic paper, becomes a straight line.

It may be added in this connection that the linear logarithmic equation $R = K V^n$ has been shown to be true theoretically, only if the factor (VL/ν), which introduces the skin or surface friction in the more complete equation

$$R = \rho A V^2 f(VL/\nu),$$

also varies as a single function of the velocity, the function

being V^{n-2}. It is common knowledge on the contrary, that for very low velocities $n = 1$ and that it rapidly increases as the velocity increases. This has lead to considerable suspicion as to the applicability of the linear logarithmic equation. Tests on a number of airship forms, however, seem to indicate that n reaches a constant value, ranging from 1.82 to 1.92 according to the model, at a comparatively low velocity varying with the model, but apparently never exceeding 30 m.p.h. For most models n becomes constant at some velocity below 20 m.p.h. and continues constant through 70 m.p.h. which is usually near the upper limit of the velocity range

The error due to correcting for the pressure gradient is even less. The correction being less than 10 per cent of the resistance, three significant figures in the gradient correction are all that can be used since the resistance values, to which the corrections are applied, are good at best only to four significant places. The pressure gradients being permanent calibration values of the tunnel, however, should be determined to the fourth significant figure. Consequently, the third figure in the correction is more accurate than the fourth in the resistance, and a negligible error results from applying it.

It seems, in conclusion, that the precision of the results of the bifilar balance is limited only by the accuracy to which the wind velocities can be uniformly maintained and determined

—Mr. Smith claims to be the first to develop and apply the pressure gradient correction to wind tunnel tests.—EDITOR

The Pacific Hawk Commercial Airplane

The Pacific Hawk is a six-place, enclosed, twin motored biplane designed by O. W Timm, engineer for the Pacific Airplane & Supply Co., to meet the demand for a small low priced pleasure or commercial ship of the twin motored type

GENERAL DIMENSIONS

Span, upper plane	52 ft. 0 in.
Span, lower plane	52 ft. 0 in.
Chord, upper plane	6 ft. 6 in.
Chord, lower plane	6 ft. 6 in.
Gap between planes at fuselage	7 ft. 2½ in.
Overall length	32 ft. 0 in.
Overall height	10 ft. 6 in.

AREAS

Upper planes, (with ailerons)	338 sq. ft.
Lower planes, (with ailerons)	318 sq. ft.
Total area	656 sq. ft
Ailerons, (four)	each 21 sq. ft.
Stabilizer	55 sq. ft.
Elevator	41 sq. ft.
Fins, (two)	each 5¼ sq. ft.
Rudders, (two)	each 13 sq. ft.
Loading, per square foot	6 lb.

WEIGHTS

Net weight, (empty)	2630 lb.
Gross weight, (fully loaded)	3950 lb.
Useful load	1320 lb.

PERFORMANCE

Maximum speed	82 m.p.h.
Minimum speed	47 m.p.h.
Climb in 10 minutes	?4,100 ft
Range of endurance	6 hr.

MAIN PLANES

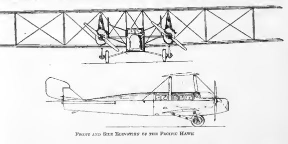
Incidence of both planes	4 deg
Dihedral, upper plane	6 deg
Dihedral, lower planes	2½ deg

The main planes are in five sections. The ribs are designed from R. A F 6 data. Beams are of I section built up of three laminations of spruce. Ailerons are attached to both upper and lower planes and are 14 ft. long and 18 in. wide, constructed of wood.

FUSELAGE

Length overall	29 ft.
Width	38½ ft
Depth (not including cabin)	36 ft
Depth (including cabin)	55 ft.

The fuselage is built almost entirely of spruce and covered with plywood from the nose to the rear of the cabin and from the tail post to the skid section. The balance is covered with linen. The cabin is constructed of aluminum and Ultra-glass is used for windows. Three double wicker seats are set in tandem. Dual Dep control is operated from the front seat. One 40 gal. gasoline tank is mounted in the nose and one 40



FRONT AND SIDE ELEVATION OF THE PACIFIC HAWK

THREE-QUARTER REAR VIEW OF THE PACIFIC HAWK COMMERCIAL AIRPLANE

gal. tank is mounted back of the rear seat. The gasoline is circulated from the main tanks to the gravity tanks in the center section by two air driven pumps. Each motor, with gas tanks etc., is an independent unit. The landing gear is of a two wheel type with the wheels under the motors and the landing shocks are taken through the motor sections. The axle is hinged to the fuselage to take the side thrust; 30 by 5 in. wheels are used. The tail skid is slung on rubber cord and the tail skid mounting is of tubular construction, designed to distribute strains evenly to the four longerons.

The stabilizer is built of wood and has a width of 14 ft. and depth of 4 ft. 3 in. The elevator is built of wood and has an overall width of 15 ft. and 3 ft. depth. The fins and rudders are built of steel tubing. Overall dimensions of the rudders are 60 in. x 36 in.

Two Curtiss OX-5 motors with 8 ft. 4 in. by 5 ft. 6 in. pitch propellers are used. Free air radiators are mounted over the motors.

N. A. C. A. Reports

RESULTS OF TESTS ON RADIATORS FOR AIRCRAFT ENGINES. Synopsis of Report No. 63, National Advisory Committee for Aeronautics.

Part I shows in tables and curves the results of measurements of geometrical characteristics of 50 types of radiators, together with such physical properties as heat transfer, head resistance, air flow through the core, power absorbed, and figure of merit. In most cases, the properties are shown for speeds running up to 120 m.p.h.

The terms used in describing the radiators and their performance are defined, the more evident relations between the properties and characteristics are stated, and applications of the results to the design of a radiator are pointed out.

It is shown that the most efficient type of radiator tested, for use at high speeds and mounted in "unobstructed" positions on the aircraft, is one whose water tubes are flat hollow plates, placed edgewise to the air stream, and continuous from front to rear of the radiator.

Part II shows in curves the pressure heads required to produce given rates of flow of water in twelve sections of radiator, each of a different type, briefly described and shown in photographs, but each with a core 8 inches square. The methods used in the tests and in computation are stated in detail, and a method is developed for estimating, by the use of twelve sets of auxiliary curves, the pressure head required for a given rate of water flow in each type of radiator, when of any size, on the assumption that losses of head at inlet and outlet of the water tubes are negligible in comparison with the resistance in the tubes of the 8-inch sections.

STABILITY OF THE PARACHUTE AND HELICOPTER. Synopsis of Report No. 80, National Advisory Committee for Aeronautics.

This report deals with the mathematical theory of the stability of bodies normally travelling vertically, especially with aircraft symetrical about a vertical axis, as is the case with the ordinary parachute. The treatment is based on the method of Bryan and Brodetsky. It is pointed out that the parachute may have a compound oscilation of a complex form, and some of these oscillations are illustrated. The conditions of stability are deduced, and rules and a chart are given which make it possible to predict the degree of stability for any parachute for which the resistance and rotary derivatives and other characteristics have been determined by wind tunnel tests or otherwise.

THE PARKER VARIABLE CAMBER RIB. Synopsis of Report No. 77, National Advisory Committee for Aeronautics.

The purpose of this report is to describe the work done by Mr. H. F. Parker in the development of a wing permitting of variation of the camber and having wider range of usefulness than is possible at a single section. The Parker rib contains two sets of diagonal wires, one of which is normally slack, and a considerable motion is possible between the extreme positions where the two sets of diagonals become taut. The report describes statical tests for strength on ribs constructed in this manner. These tests were very satisfactory, the ribs comparing favorably in strength with those built up rigidly in the ordinary way. A series of aerodynamic tests on sections of the various forms which the Parker wing would assume in passing from one extreme position to the other are also included, the wings having been tested as monoplanes and in biplane and triplane combinations of various types. The maximum absolute coefficient for the Parker wing at its high-lift setting was .77, while the minimum drag coefficient for a wing of the form which the Parker wing has with the other set of diagonals taut (the form then being approximately symmetrical about a center line) was .007. The ratio of maximum lift to minimum drag coefficient was therefore exceptionally high.

Copies of these reports may be obtained upon request from the National Advisory Committee for Aeronautics, Washington, D. C.

THE LIMITING VELOCITY OF FALLING FROM A GREAT HEIGHT. Synopsis of Report No. 78, National Advisory Committee for Aeronautics.

Report No. 78, entitled "The Limiting Velocity in Falling from a Great Height," by Professor E. B. Wilson, deals with the velocity in falling bombs when the variation in air density with height is taken into account. It is shown that bombs must be dropped from considerable altitudes in order that they may reach a maximum velocity before striking the ground.

Duralumin

By E. Unger and E. Schmidt

The use of duralumin in the construction of aircraft makes an account of the properties of this material desirable especially with reference to its working qualities as developed by experience.

Composition, Specific Gravity and Melting Point

Duralumin is made in various compositions and has, with the exception of small quantities of impurities, the following composition:

Aluminum	95.5 to 93.2 per cent
Magnesium	.5 per cent
Copper	3.5 to 5.5 per cent
Manganese	.5 to .8 per cent

Lead, tin and zinc which, as is well known, have an unfavorable influence upon the permanence of aluminum alloys, are not found in duralumin.

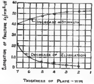


FIG 1.

The specific gravity of duralumin varies according to composition and hardness from 2.75 to 2.84. The melting point is about 650 deg. cent.

Working of Duralumin

Like other metals, duralumin can be rolled into plates and shapes and behaves in a similar manner, in that the elongation decreases as the hardness of rolling increases. Tube blanks, however, can be made only by pressing and not by oblique rolling method.

Fig. 1 shows the increase in tensile strength and decrease in elongation of a duralumin plate as its thickness is reduced by cold rolling from 7 mm. to 2 mm. The strength increases from 41 kg. to about 54 kg. per sq. mm. while the elongation

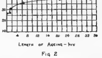


FIG 2

falls from 22.7 to 2.3 per cent. The curve shows that the elongation decreases very rapidly with the very first reduction in thickness.

about 400 deg. Cent. very well.

However, duralumin can be worked hot at a temperature of

Tempering

Duralumin can be tempered, like steel, by heating and sudden cooling. For this purpose plates, tubes, and shapes are heated to between 480 deg. and 510 deg. and quenched, then aged, that is, the treated material is simply set aside. The original strength characteristics are very nearly restored after the quenching but the tensile strength continues to grow with the time of ageing, from 35 to 50 kg. per sq. mm. The elongation does not decrease but remains at least the same and usually increases slightly. In practice the greatest strength is reached after about five days of ageing.

When heated to over 530 deg. Cent. duralumin becomes

TABLE I.

Symbol for Composition	Condition	Method of Preparing	Elastic limit kg/mm²	Tensile strength kg/mm²	Elongation in per cent	Modulus of elasticity kg/mm²	Sections available
68 lb 1/3	tempered only	tempered	24 to 26	35 to 40	20	about 500,000	Tubes, plates, strips, bars & shapes
68 lb 1/3	1/2 hard	tempered and cold rolled	38	40 to 42	16 to 14	500,000	Tubes, plates, strips, bars
681a	tempered only	tempered	25 to 27	38 to 40	20 to 18	600,000	Tubes, plates, strips, bars & shapes
681a	hard	tempered and cold rolled	30 to 32	44 to 46	11 to 10	—	Tubes, plates, strips, bars & shapes
681b	tempered only	tempered	26 to 28	36 to 40	18 to 16	600,000	Tubes, plates, strips, bars & shapes
681b	hard	tempered and cold rolled	32 to 34	45 to 48	11 to 10		Tubes, plates, strips, bars
N	tempered only	forged rivets are tempered	30	32 to 38	16 to 14	Shear strength up to 6 mm. diam. 25 kg/mm²	Finished rivets

Duralumin is made under this name in Germany by the Duerener Metallwerke, Dueren (Rhld), and under the name of Bergmetall by Carl Berg, Eveking (Westf.).

* Translated from *Technische Berichte* Vol. III, Section 6, by Starr Truscott, Aer. Eng., Bureau of C. & R., U. S. Navy

unusable. Consequently the treating is carried on in a bath of nitrates whose temperature can be carefully regulated and watched During the ageing of the metal work cannot be done on it which would change the section as in that case the strength will not increase any more. After the completion of ageing, the material can be re-rolled in order to obtain smooth surfaces. The strength is thereby increased at the expense of elongation.

Fig 2 shows the increase of strength during ageing The tensile strengths were determined by the Ericson test with 0 385 as a coefficient. This value was obtained from the experiments described below.

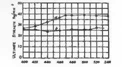


Fig 3

Experiments have been made (see Fig 3) by the Duerener-Metallwerke to determine the most favorable quenching temperature. The curve "a" shows the variation in the strength of duralumin which had been aged for four days with the variation of quenching temperature Curve "b" shows the strength immediately after the quenching. The strengths were determined in both cases by the Ericson test.

As the material may warp in tempering it is not good practice to temper riveted parts. Such parts should be tempered before they are riveted.

Ericsons Test Apparatus
Fig 4

Strength Properties

Duralumin is delivered in various compositions which have different properties according to the purpose for which it is intended to be used. It is therefore important that the concern supplying the material should be informed regarding the nature of the working proposed. In Table I below are assembled the strength figures of some duralumin compositions made by the Duerener Metallwerke.

The modulus of elasticity of the hard composition 681a was found by the Technische Hochschule Aachen to be 700,000 kg per sq cm Making allowance for the possible effect of vibrations on the modulus of elasticity it appears better to use not more than 650,000 kg. per sq. cm. in computations

In judging the suitability of a material for use in stressed parts not only the tensile strength but also the ductility is of great importance This can be determined by bending strips backward and forward through 180 deg over a definite radius—usually 5 to 10 mm.—the number of bends before fracture being taken as a measure. Other conclusions as to the ductility can be obtained from the Ericson test (see Fig 4) The plate to be tested is pressed through a ring, b, by a head, a, until a tear shows on the upper surface of the sheet. The depth of the impression is then a measure of the ductility.

In Table II there are compared strength values, number of bends (over 5 mm. radius and through 100 deg) and depths of impression as observed on Bergmetall plates and steel plates of equal thicknesses.

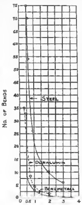


Fig 5

Although the strength values of the steel plates are less than those of the duralumin plates, nevertheless one can compare the figure as to number of bends and depths of impression without correction, since it is possible to obtain steel plate with higher strength which also possesses great ductility.

The number of bends (See Fig 5) for both metals decreases with increased thickness. For steel, however, they lie considerably higher than duralumin. The difference is least for plates under .5 mm in thickness. For thicker plates of duralumin the number of bends decreases very rapidly At plate 2 mm. thick breaks over a 90 deg. bend, a plate 4 mm thick over a 45 deg. bend For these results duralumin might be referred to as "cold short" for thicknesses greater than 1 mm. This property makes it unsuitable for highly stressed parts which

TABLE II

Strengths, No of bends, depths of impressions for Steel and Bergmetall

	STEEL				BERGMETALL			
Thickness of Plate	Strength kg/mm²	Elongation per cent	No Bends	Depths of impression mm	Strength kg/mm²	Elongation per cent	No Bends	Depth of impression mm
0.5	38	10 6	78	7.2	47	10 5	68	6 5
1	34	15.8	24	9.8	47	11 0	3	4 2
2	36	12 0	10	10 0	48	11 0	Fractured at 80°	3 4
3	40	17 7	6	13	46	14 1	Fractured at 60°	3 0
4					48	9 7	Fractured at 45°	2 9

must at the same time withstand vibrations This is of prime importance in connection with the bent lug plates which are ordinarily used in aircraft for taking wire terminals In these lugs vibrations undoubtedly occur during flight which would reduce the strength of the duralumin and might cause sudden fracture

Exactly how vibrations influence the modulus of elasticity has not yet been determined, although experiments along this line are already under way.

A comparison of the depth of impression of steel and duralumin shows (See Fig 6) that for steel the depth of impression increases with the thickness of the material while for duralumin it decreases As a result of a peculiarity of the testing machine used the greatest stress occurred at a point which was from 5 mm to 8 mm from the vertex of the depression In this locality the material began to flow before cracking It is obvious that thick plates of ductile material may be stretched more easily on the upper surfaces and consequently deeper impressions obtained than with thin plates, since for thick plates more material can flow before fracture occurs. A similar course of reasoning can be used to explain the decrease of depth of impression with increasing thickness of plate in the case of material of less ductility

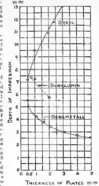


Fig 6

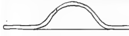


Fig 7
Steel Plate

Fig 8
Duralumin Plate

On the upper surface of the test pieces there occur high tensile stresses at the point above mentioned, which increase with the strength of the plate. As the material flows only to a small degree, cracks very soon appear and extend into the interior. The process described can be followed on the sections of a steel plate of about 40 kgs. per sq mm. strength and a duralumin plate, Fig 8. The flow before fracture of the steel plate is plainly recognizable while the duralumin plate shows hardly a sign of it.

Fig 9
Outside Fracture of Duralumin Plate

Fig. 9 is a photograph of a test sample of strong duralumin plate after fracture in which the material suddenly split in all directions.

For flanging and pressing tempered duralumin is consequently suitable only in the thin gauges.

Influence of HEAT and COLD

Heat has an important influence on the strength of duralumin. According to the results obtained in tests by the Central Bureau for Scientific Investigation, Neubabelsberg, when heated the strength decreases 10 per cent for an increase in temperature of 100 deg. and about 20 per cent for an increase of 150 deg (see Fig 10) The loss in strength increases with the increase of temperature. The elongation increases on first heating to a hardly appreciable extent, while between 150 and 200 deg it decreases. At 250 deg the elongation becomes the same as at room temperature. With further heating the elongation increases with increasing temperature Consequently wherever duralumin is exposed to heat the possible decrease of strength must always be considered.

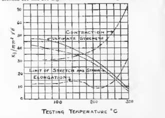


Fig 10

As opposed to the foregoing, the influence of cooling on the strength properties is less unfavorable. The Central Bureau for Scientific Investigation has made tests on this also (see Table III).

TABLE III.

Influence of Cold on the Strength of Duralumin

Testing Temperature	The bar was tested in	Limit of stretch and strain	Tensile Tests Ult. Strength kg./mm²	Elongation per cent	Impact Test Work of breaking kg./mm²
+ 20°	Air	24 0	42 3	21 0	3 0
0	Snow	23 0	45 0	21 8	2 8
— 20	Mixture of snow and table salt	24.8	46 7	23 1	2 7
40	Mixture of snow and calcium chloride	24 0	44 0	22 1	2 7
— 80	CO_2 snow	25 2	44 4	22 7	2 7
—190	Liquid Air	32 0	53 7	20 7	2 6
+ 20	Air	23 0	42 3	23 2	2 4

TABLE IV

Effect of Weathering on the Strength of Duralumin

Testing Date Alloy 681a	Dec 1909 Strength kg./mm²	Dec 1909 Elongation per cent	Nov 1910 Strength kg./mm²	Nov 1910 Elongation per cent	Nov 1911 Strength kg./mm²	Nov 1911 Elongation per cent	Dec 1912 Strength kg./mm²	Dec 1912 Elongation per cent
Round Bar	41 7	20	42.2	21	42	21 1	42 8	18 3
Bar (thick)	39 1	20	38 7	19 0	39 3	18 9	40	20
Bar (thin)	42 0	20	38 1	18 3	38 9	18	42 3	18 5
Wire (thick)	46 0	20 1	45	46 1	44 0	19 7	44.5	18 8
Wire (thin)	46 8	20	44	18 0	42 5	18 7	45 2	18 5

The strength and elongation increase somewhat with the decrease in temperature. The work represented by the blow in the impact tests is not decreased when the material is affected by cold, so that one can safely assume that the cold encountered in flight has no unfavorable influence on duralumin.

Experiments on the influence of weathering on the strength of duralumin, which have been carried on by the Deurener Metallwerke for three years, have shown that an observable decrease in the strength properties can be noticed (see Table IV).

The Deurener Metallwerke have also carried on for about a year, experiments on the influence of the electrolytic effect from junctions of duralumin with iron or steel. These were made by riveting duralumin bars to iron plates and then placing them in artificial sea water. There resulted only an insignificant destruction of the iron and a reduction in weight of the bars of about 23 per cent so that no considerations exist against the use of duralumin and iron junctions in aircraft.

Summary

Duralumin has a strength of 35 to 40 kg per sq. mm. and an elongation of 10 to 15 per cent. The stretching strain limit lies very high, about 28 to 32 kg. per sq. m. The modulus of elasticity is about 600,000 to 700,000 kg per sq. cm. It is very brittle, especially in thicknesses above 1 mm., and consequently sensitive to bending to and fro (alternating).

Bent plate fittings, with bent lugs which must resist vibrations, are best not made out of duralumin but of sheet steel. For stressed parts which, while in flight, are exposed to an increase in temperature of more than 100 deg. Cent., the use of duralumin is objectionable unless a correspondingly smaller strength value is used in computations. Cold has no harmful influence on duralumin. The joint between iron and steel and duralumin can be made with electrolytic action occurring. Pieces, which for better working must be heated, must be in all cases re-tempered after completion.

Book Review

AEROPLANE STRUCTURES. By A. J. S. Pippard and J. L. Pritchard. With Illustrations and Diagrams. (359 Pages) Longmans, Green and Co., Fourth Ave. & 30 St. New York.

With the publication of this book the first comprehensive work dealing with the subject of strength calculations of airplanes is now available to airplane designers. The whole subject of the structure of the airplane is treated from the strength standpoint primarily but an adequate discussion of all closely related factors is included.

The thoroughness with which the stresses are handled reflects the enormous advance made in the structural technique of the airplane. It may be safely said that the problem, difficult as it is, of providing sufficient strength with satisfactory lightness has been placed on an engineering basis, and that the aeronautical engineer will be able to keep pace with new types of construction being developed. The subject of metal construction has not been gone into in the present work, but much of the subject matter is applicable to this newer form of construction as well as to the conventional wood structure. A discussion of the secondary stresses produced in thin metal sections would round out the volume.

The treatment is well adapted to the needs of both student and engineer. A number of proofs of the theorems used are given and although the mathematics are difficult in places for drafting room use, the results are in such form that they may be applied easily.

The book is well illustrated, although the types of construction shown are naturally British.

Details of construction are carefully considered, and sound methods of design given. Strut design is treated fully including the effect of tapering and routing.

Perhaps the best part of the volume is that which treats of loads imposed on various parts of the machine under all the important conditions to which an airplane is subject. The discussion includes the load factors which should be used for various types of machines.

Two chapters are devoted to strength tests of materials and structures. The method of least work is becoming of frequent use and is explained in a simple manner.

The book is well written and is a valuable addition to the literature of aeronautical engineering.

Model Test for Strength and Deformation of Non-Rigid Airship Hulls

By Comdr. J. C. Hunsaker, C. C., U. S. N.

Suppose the model filled with water of buoyancy in air—1000 kg. per cu. m.—and the ship filled with hydrogen of a buoyancy equal to 1.1 kg. per cu. m.

Suppose the model made of same fabric as the ship.

Suppose the model scale $\frac{1}{n}$, which gives the same relative deformation as the ship, that is, the model, when deformed, is geometrically similar to the deformed ship.

Suppose the model subject to an inner pressure such that the intensity of stress at corresponding points of model and ship are equal.

Geometric Relations. Call cross sections parallels and intersections with plane through axis of rotation meridians.

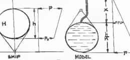


FIG. 1

At any point of ship's envelope there are two radii of curvature r_p in the parallel and r_m in the meridian through the point. If the pressure at this point is p, the tensions in the fabric are.—

$$p = \frac{t_p}{r_p} + \frac{t_m}{r_m}$$

This equation is indeterminate because containing two unknowns t_m and t_p, but tension in a parallel is given by.—

$$t_m = \frac{\pi r_p^2 P}{2 \pi r_p \cos A} = \frac{r_p P}{2 \cos A} \qquad (2)$$

where A is slope of tangent to a meridian to axis. Hence t_m and t_p are determined as linear functions of the radii of curvature, the pressure, and slope of the meridian.—

$$t_p = r_p P \left[1 - \frac{r_p}{2 r_m \cos A} \right] \qquad (3)$$

For corresponding points on model and ship, $\frac{r_p}{r_m}$ and $\cos A$ are constant. Hence for the same tension on both, the pressures must vary inversely as the radii of curvature or as n. The model has, therefore, n times the pressure p of the ship, and the problem becomes that of arranging that this pressure relation in practice shall hold for all points, or that.—

$$\frac{p^1}{p} = n \qquad (4)$$

Pressure Relations.—The buoyancy of hydrogen in air is 1.1 kg. per cu. m. and if the pressure at lowest point of balloon is p_o in kg. per sq. m. the pressure at a point h meters above it is $= p = p_o + 1.1h$ (5)

In the water-filled model, hung upside down on its suspension, let us have a head of water as shown in Fig. 1, such that the pressure on the belly is np_o, that is, a head of water given by —

$$x = \frac{np_o}{1000} \qquad (6)$$

and the pressure p^1 at any point h corresponding to h^1 is given by —

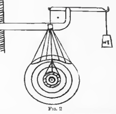


FIG. 2

$$p^1 = 1000\ (x + h^1) \qquad (7)$$

but by (4).—

$$\frac{p^1}{p} = \frac{1000\ (x + h^1)}{p_o + 1.1\,h} = \frac{np_o + 1000\ \frac{h}{n}}{p_o + 1.1\,h} = n$$

and solving for n, we have —

$$n = 30\ 18 \qquad (8)$$

The problem is therefore solved by making a water-filled model to scale $\frac{1}{30\ 18}$ and giving it a head of water above its highest point (belly) of $x = .03018p_o$ m. The pressure on ship p_o may be assumed given by a head or column of gas y, determined by:—

$$p_o = 1.1y \qquad (9)$$

Then by (4) and (7),—

$$\frac{p^1_o}{p_o} = n = \frac{1000x}{1.1y}$$

and from (8), $\frac{y}{x} = n = 30\ 18$ (10)

The head of water must then be $\frac{1}{30\ 18}$ the head of hydrogen assumed for the ship. The pressure p_o is ordinarily about 20 kg per sq. m., which is an equivalent appendix length or head of gas of $y = 18.2$ m. The head of water x will therefore be about 60 3 cm.

In practice the necessary pressure p_o to hold the balloon stiff will be found by calculation from the necessary head of water x found by experiment to hold the model stiff.

Refinements: The ratio of volumes is n^3 and ratio of buoyancies —

$$\frac{\text{B ship}}{\text{B model}} = n^3 \frac{1.1}{1000} = n = 30.18$$

Hence model of 6000-lb. ship weighs 200 lb. approximately.

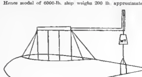


Fig. 3

In the ship the weight of hull is not carried by suspension, and may amount to as much as 25 per cent of total buoyancy. If the water model is hung upside down, the load on the suspension is too great because it includes the weight of fabric. The weight of this fabric is $\frac{1}{n^3}$ of the weight on the ship since same stuff is used on both. For weights to vary as buoyancy, this should be only $\frac{1}{n}$ and hence 1/30 of correct weight. The total weight hanging on the suspension is, therefore, greater relatively than in the ship and the condition of the model test more severe and hence on the safe side.

This error may be corrected by putting on an air sack inside the model envelope to displace the required weight of water necessary to represent envelope weight. A sack to displace about one-quarter of the total volume is sufficient. Pressure and stress are not affected. The sack should be a long sausage extended from end to end. An automobile inner tube may be cut to form a straight tube with ends sealed and blown up with pump until the weight on the suspension is reduced 25 per cent.

The principal weight put on the envelope is the weight of fins and rudders, which may be estimated for the ship and a corresponding load on model $\frac{1}{n}$th as much applied where the fins come as shown in sketch.—*Aircraft Technical Note, Bureau of Construction and Repair, Navy Dept.*

Note on Measurement of Speed of Airplanes

By J. G. Coffin

Director of Research, Curtiss Aeroplane and Motor Corp.

The writer was very much astonished to learn that in airplane speed trials over a measured course it was considered necessary to wait for a time when little or no wind was blowing, or, if any, that it had to be along the course.

This restriction, of course, reduces considerably the available periods for making trials and, in fact, renders them impossible for days at a time.

While the writer does not believe that these restrictions are universally accepted he believes a short resume of the correct

FIG. 1.

theory will not be out of place at this time and in particular a simple graphical method for the computation of the results which he has not seen published elsewhere is here given for the first time.

Consider a measured course AB of length S and let the observed time of flight from A to B be t_1 and the observed time of flight from B to A be t_2.

Assume that the wind speed W is constant in direction and magnitude during these measurements. The true relative airspeed of the airplane V is of course also assumed constant.

Referring to Fig. 1, let α be the angle the wind makes with the course. The longitudinal axis of the airplane must make some angle β_1 with the course, such that the resultant of the true relative airspeed of the plane and the velocity of the wind shall be along the course. Let this resultant speed be U_1. On the return flight let the angle made by the plane axis with the course be β_2 and the resultant speed along the course be U_2.

It is quite evident that the component, normal to the course, of the vector V must be equal and opposite to the component normal to the course of the wind vector W, in both going and returning.

Hence

$$V \sin \beta_1 = W \sin \alpha \tag{1}$$
$$V \sin \beta_2 = W \sin \alpha$$

and hence $\beta_1 = \beta_2$

The longitudinal axis of the machine points along the vector V when flying along the course and makes the same angle with the course, as shown in the figure, in either direction of flight. Let this angle be β.

Projecting the vectors W and V along the course we have

$$U_1 = V \cos \beta + W \cos \alpha \tag{2}$$
$$U_2 = V \cos \beta - W \cos \alpha \tag{3}$$

Hence
$$V = \frac{U_1 + U_2}{2} \cdot \frac{1}{\cos \beta} \tag{4}$$

and
$$W = \frac{U_1 - U_2}{2} \cdot \frac{1}{\cos \alpha} \tag{5}$$

Also, from (1) and (4) and (5)

$$V \sin \beta = W \sin \alpha = \frac{U_1 + U_2}{2} \tan \alpha$$

$$V \cos \beta = \frac{U_1 + U_2}{2}.$$

we get by squaring and adding

$$V^2 = \left(\frac{U_1 + U_2}{2}\right)^2 + \left(\frac{U_1 - U_2}{2}\right)^2 \tan^2 \alpha \tag{6}$$

and similarly

$$W \sin \alpha = V \sin \beta = \frac{U_1 + U_2}{2} \tan \beta$$

$$W \cos \alpha = \frac{U_1 - U_2}{2}$$

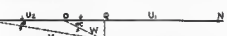
so that

$$W^2 = \left(\frac{U_1 + U_2}{2}\right)^2 \tan^2 \beta + \left(\frac{U_1 - U_2}{2}\right)^2 \tag{7}$$

Formulae (4) and (6) give the solutions for V in terms of β and α respectively, while (5) and (7) serve to determine W in terms of α and β respectively.

The following graphical method is a very simple one and solves equations (4) and (6).

Knowing S, t_1 and t_2 compute U_1 and U_2 and lay off U_1 and U_2 as shown in Fig. 2 below, where $QM = QN$.



From M draw a line MP making angle β with MN, then MP is the true relative airspeed sought for. Evidently

$$MP = \frac{U_1 + U_2}{2} \cdot \frac{1}{\cos \beta}$$

If α is known rather than β, draw OP making an angle α with MN, then as before MP is the true relative airspeed. From Fig. 2 we see that

$$PQ = OQ \tan \alpha = \frac{U_1 - U_2}{2} \tan \alpha$$

$$MQ = \frac{U_1 + U_2}{2}$$

Hence

$$V^2 = \overline{MP}^2 = \left(\frac{U_1 + U_2}{2}\right)^2 + \left(\frac{U_1 - U_2}{2}\right)^2 \tan^2 \alpha$$

which is equation (6).

An error which is sometimes made is to divide twice the length S of the course by the sum of the two time intervals instead of using the correct equation (4).

That this error may be serious can be seen by the following example, where for simplicity the wind is along the course, that is $\alpha = \beta = O$

The true airspeed by (4) is $\frac{U_1 + U_2}{2}$ whereas the airspeed computed by the erroneous rule is

$$\frac{2S}{t_1 + t_2} = \frac{2S}{\frac{S}{U_1} + \frac{S}{U_2}} = \frac{2\,U_1 U_2}{U_1 + U_2}$$

Let the windspeed and airspeed be such that

$$U_1 = 100 \text{ m.p.h.}$$
$$U_2 = 60 \text{ m.p.h.}$$

The true airspeed is

$$\frac{100 + 60}{2} = 80 \text{ m.p.h.}$$

whereas the erroneous airspeed is

$$\frac{2 \times 100 \times 60}{100 + 60} = 75 \text{ m.p.h.}$$

an error of 5 m.p.h.

It is better to determine β and use formula (4) than α. First because the amount and direction of the wind relatively

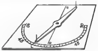


FIG. 3.

to the ground at the altitude of the airplane is the value required and these are probably different from values observed at the ground. Second, it is not convenient to determine α from the airplane.

To determine β, on the other hand, is quite a simple matter and can be done as follows —

A horizontal board on which is pasted a circular scale divided into degrees, has a movable arm pivoted at the center and provided with two sight lines at its ends. The board is attached to the machine so that the OO line is along the flying longitudinal axis of the machine.

The pilot from time to time during the test sights along the course at the angle OL which should be the same going and returning except for sign. The average value of these angles is the β of formula (4).

Fig. 4

The course AB should be determined so that two other points C and D are in line with AB. These points can be anything of prominence in the landscape, such as church steeples, prominent trees, water towers, etc., the idea being that starting somewhere between C and A the course AB is flown keeping BD in line; on the return starting somewhere between D and B the course BA is flown, keeping AC in line.

There is an ingenious method derived from an English report which deserves mention here. Its advantage is that no course is needed. The airplane flies so as to pass at a constant altitude directly over the observer who sights with a transit, reading off the angles γ after a given time interval has elapsed. The method is shortly described below.

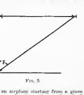


Fig. 5

In still air, if an airplane starting from a given point O flies in three or more directions, the speeds will all be equal and the ends of the velocity vectors etc., will lie on a circle. OQ_1, OQ_2, OQ_3 etc. are observed airplane speeds. The radius of circle is the true airplane air speed, OO' is true wind velocity.

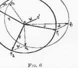


Fig. 6

Hence the method. Determine the ground speeds in three or more directions. Plot these *velocities* and by means of a transparent set of concentric circles find the one with center O' that passes through the points Q_1, Q_2, Q_3, etc. The radius of this circle is the true plane *speed* in still air, and the distance OO' is the true wind *velocity*.

Wind Tunnel and Airship Model Testing

By R. N. Wing

Aeronautical Engineer, Goodyear Tire and Rubber Co.

The information obtained from wind tunnel tests on models of complete airplanes, airships and their various parts has been of utmost value in the rapid development of aircraft during the last decade.

The purpose of wind tunnel testing is to investigate the action of the air around bodies moving through it and to measure the resulting air forces or reactions upon these bodies under various conditions. The fundamental principle upon which wind tunnel testing is based is that of "relative motion," which is, briefly, that the reaction between a body and the air is the same in amount and position whether the body is moved through still air at a certain speed or whether the body is held immovable, and a stream of air of same relative velocity and direction impinges upon the body.

Methods of Aerodynamical Testing

Before going into a detailed description of the wind tunnel, let us consider briefly the various methods of obtaining aerodynamical data, namely the towing method, the whirling arm and the wind tunnel. We will not here consider the testing of the full size machines in actual flight, but such tests should be taken advantage of for checking the other methods whenever possible.

(a) *Towing Method.* This method, used at the Aerotechnic Institute of St. Cyr, France, permits the testing of full size surfaces and even full size airplanes. The apparatus consists of an electric car which is operated along a straight track one mile long and above which are supported the surface to be tested and the measuring instruments.

The main disadvantage of this method is the inability to obtain still air and it is practically impossible to repeat a test under exactly the same conditions as the wind is sure to change somewhat in direction or velocity. Because of the high speeds of test, the resulting short duration of time for experimental observation reduces the precision of the results.

(b) *Whirling Arm.* This method is used by the Vickers Co. of London in testing propellers. This apparatus consists of a horizontal arm 50 ft. radius which revolves about a fixed vertical axis. The model is tested at the outer end of the revolving arm. The measuring instruments have to take care of the centrifugal force. A large building houses this apparatus. Due to the curvilinear path produced, this method might be of value in testing the stability of an airship model which is inherently stable only in a curvilinear path of a certain radius of curvature.

(c) *Wind Tunnel.* This apparatus consists of a channel through which air is drawn at a known velocity by means of an exhaust fan or propeller. The wooden or metallic model to be tested is mounted in this channel upon an aerodynamic balance by means of which the various air reactions are accurately measured, namely *drift* or *drag*, which is the horizontal component of the resultant air reaction parallel to the direction of air flow through the channel, *lift*, which is the component normal to the direction of air flow, and *turning moment* (yawing or pitching), which is the moment produced by the resultant air force tending to turn the model about its point of support.

Direct resistance or drift can also be obtained in a wind tunnel by suspending the model by means of wires and noting the deflection.

Advantages of Wind Tunnel

The main advantages of the wind tunnel over other methods of testing are —

1. A convenient, accurate, safe and relatively inexpensive method of obtaining valuable data for use in the proper design, analysis and performance prediction of all types of aircraft.
2. The ability to produce a steady wind and to control its velocity and direction for as long a period of time as is necessary for accurate observations.
3. The possibility of investigating the air flow in the vicinity of the model and of measuring the pressure at any point along the surface of the model.
4. The ability to repeat the conditions of a test at any time in order to check results.

Principal Types of Wind Tunnels

There are three distinct types of wind tunnels, namely, the N. P. L. (National Physical Laboratory) of Great Britain, the Goettingen of Germany and the Eiffel of France.

(a) *N. P. L.* This type tunnel consists of a long uniformly square cross section channel, in which the model is supported upon the vertical spindle of the aerodynamic balance which projects up through the bottom of the tunnel. The remainder of the balance is located beneath the tunnel, where the operator takes his readings. A bell shaped collector is attached to the mouth of the channel, and honeycomb sections of metal are located in the channel near its mouth in order to straighten out the air flow and make it parallel to the sides. At some distance beyond the working or testing portion of the square channel it expands into a larger circular section in which the propeller or exhauster blower is located. This propeller may be driven by means of a belt connected to a motor beneath. Beyond the propeller is a large diffusing chamber, the sides top and bottom of which are of lattice work in order to allow the velocity to be gradually dissipated. This tunnel is located in a separate room or building so that the air discharged from the diffuser is again drawn into the collector. Wind tunnels of this type are used by the Massachusetts Institute of Technology, the Curtiss Aeroplane & Motor Corp., the Washington Navy Yard and the University of Washington. The usual wind speed obtained in a 4 ft. N. P. L. type tunnel with a 15 hp. electric motor is about 30 m.p.h. The Curtiss Aerodynamical Laboratory, by using a 100 hp. Curtiss motor direct-driving a propeller, obtains a range of velocity from 20 to 75 m.p.h.

(b) *Goettingen.* This type differs from the N. P. L. and Eiffel tunnels in that it provides a *closed* circuit, the testing portion of the channel being a square section. It has been extensively used for testing airship hulls. The Goettingen tunnel is 6 ft. 6 in. square and a wind velocity of 22 m.p.h. is obtained with a 30 hp. electric motor driving a blower.

The large wind tunnel of the U. S. Navy Department is an 8 ft. square tunnel of this type and is operated by means of a 500 hp. electric motor driving a suction blower. A wind velocity of 75 m.p.h. may be obtained, but tests are generally made at a speed of about 60 m.p.h. Models of both airplanes and airships are tested in this tunnel.

(c) *Eiffel.* This type consists of a circular bell shaped collector, a large laterally air tight experimental chamber and an expanding trunk or diffuser from the experimental chamber to the suction blower. The tunnel is located in a large room and the air from this room is drawn into the bell shaped collector from which it passes through a honeycomb baffle to straighten its flow, across the exprimental chamber with a uniform velocity into the expanding trunk, from which the suction blower discharges it at a low velocity back into the room.

The large Eiffel tunnel has a 6½ ft. diameter air stream and a 50 hp. motor, driving a blower, can produce velocities from 4 to 72 m.p.h.

The Curtiss 7 ft. wind tunnel at Garden City, Long Island, is of this type. It is operated by a 400 hp. Liberty motor direct-driving a three blade 12 ft. diameter propeller, and velocities from 20 to 90 m.p.h. are obtained.

The Boeing 5½ ft. tunnel at Stanford University, extensively used for testing propeller models, is also of the Eiffel type, and a wind velocity of 40 m.p.h. is obtained by means of a 20 hp. induction motor, belt-driving a propeller.

Apparatus

The wire suspension method requires the least expensive apparatus for determining the direct resistance of a model. This consists of two long fine steel wires for suspending the model, two horizontal wires with a ring at the middle of each one to slip over a small rod in each end of the model in order to guide the model laterally and prevent it from turning and twisting, a telescope to measure the backward deflection of model, a means of determining the weight of the model and a

measuring tape for obtaining the length of the suspension. Two extra steel wires, similar to the suspension wires, are necessary for obtaining the correction due to the resistance of the suspension wires.

The aerodynamic balance embodies the mechanical principle of moment. It consists of a vertical arm and two horizontal arms at right angles to each other, and is free to pivot about horizontal knife edges or else a single point. The model to be tested is fastened to the top of the vertical arm and known weights are moved out on the horizontal arms exactly the same as any weighing scale, in order to balance the air force on the model. The model and balance arms are mounted on knife edges restricting the motion of the model to either backward or else sidewise motion, one at a time. The balance in the Curtiss 7 ft. tunnel pivots on a point so that the lift and the drift are both measured at the same time.

For measuring the "turning moments" the apparatus is made free to turn or rotate about its vertical axis. Another horizontal arm connected to the vertical one operates a right angle balance, or weighing scale which measures the turning moment directly in in. lb.

Wind velocity is measured by means of a Pitot tube or else a Krell gauge which has been calibrated with a standard Pitot tube.

(d) *Pressure distribution on model.*

A small copper tubing imbedded in the surface of the model

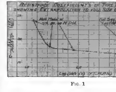


Fig. 1

is connected to a manometer by means of flexible tubing. Very small holes drilled in the copper tube normal to the surface of model, permit the measurement of the pressure distribution along the model. During an observation all holes, excepting the one in question are plugged up with wax.

Results

Standard Conditions. The results of all wind tunnel tests are reduced to a standard condition of 15 deg. Cent. and 760 mm. Hg, in order that they may be used and compared directly, without knowing the separate test conditions.

Coefficients. These results may be expressed directly in pounds, drift and lift and inch pounds turning moment on the model itself, but it is more convenient to have them expressed as coefficients, in order to apply them to full size machines and for comparison of the aerodynamical characteristics of various shapes.

The form of these coefficients depends upon the use of the bodies. For instance, in an airplane where the lift and drift vary directly with the area of the wings, other conditions remaining constant, the lift and drift coefficients are expressed in terms of *area* by following formulae:

$$K_y = \frac{L}{AV^2} \qquad (1)$$

$$K_x = \frac{D}{AV^2} \qquad (2)$$

where K_y and K_x are respectively the lift and drift coefficients, L the total lift, D the total wing resistance in lb., A the area of the wings in sq. ft., and V the velocity in m.p.h.

In an airship, where the lift or buoyancy varies directly with the *volume*, the resistance coefficient should be expressed in terms of *volume* as in the following formula:

$$C = \frac{Rg}{\rho\,(Vol^{2/3})\,V^2} \qquad (3)$$

where R = resistance in lb.,
g = acceleration of gravity in ft./sec² = 32.2
ρ = density of air in lb./cu. ft. = .07635 under standard conditions,
Vol = volume in cu. ft.,
V = velocity in ft./sec.

This makes C a non-dimensional coefficient.

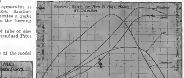


Fig. 2

Model to Full Size

In order to make the results of model tests more nearly applicable to the full size machines or parts, it is now customary to test the models throughout as high a range of speeds as possible and then to plot these coefficients against the VL ratio, where V is velocity and L is the linear dimension. This model VL even with the highest possible wind tunnel air ve-

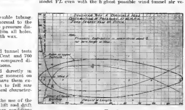


Fig. 3

locities comes way below that of the full size ship, so coefficients are often plotted to a log VL base and extrapolated for values of full size conditions.

For airships it is more appropriate to use $(V\ (Vol^{1/3}))$ as a base instead of VL.

The model resistances are also plotted against velocity on logarithmic paper and the slope of this line gives the exponent of the velocity according to which the resistance varies, Fig. 1.

Lift, drift and moment readings are taken at various angles of deflection (incidence or yaw), then vector diagrams can be

drawn which show graphically the resultant air forces in position, direction and amount

Fig 2 shows the results of various tests on the Goodyear Pony Blimp type A hull (described in AVIATION, Jan. 15, 1920), namely lift, drift and turning moments on model Pressure distribution along the surface at 0 deg and 5 deg yaw, turning moments on full size hull, and performance

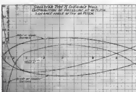


FIG. 4

curves showing the estimated resistance of the complete airship and the effective hp required at various speeds, i e, hp to be delivered by the propeller are shown in Figs. 3, 4, and 5. The resistance coefficient used here for calculating the resistance of the full size hull was obtained by extrapolation on Fig 1 The actual test flight of the Pony Blimp was a good check on the accuracy of the estimated resistance of this airship

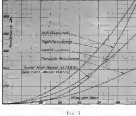


FIG. 5

Conclusion

The results of wind tunnel tests are very useful in improving the design of aircraft, cutting down resistance by proper streamlining exposed parts, developing efficient shapes, determining the proper size, nature and location of lifting and control surfaces and ascertaining the amount and position of the air loads which will come upon the various parts in flight

They are very valuable in predicting the performance of aircraft, including the maximum, minimum and most economical speeds, the balance of the machines in flight and their dynamic stability.

It is absolutely essential in designing propellers for any given machine and power plant, to know in advance the maximum speed which the machine can attain and the corresponding thrust at that speed in order that the propeller shall have the maximum possible efficiency and be most suitable. A performance estimate, based on results of wind tunnel tests on a model of such a machine or its various parts, is extremely useful in this connection.

It is impossible to estimate the number of lives which have been saved and the useless expense which has been avoided in developing aircraft, by the proper application of results and principles determined by wind tunnel testing.

Aluminum Alloys

An interesting and highly informative lecture under the above title was given by Dr Rosenhain at the Royal Society of Arts recently in London

The lecturer outlined the work carried out at the National Physical Laboratory, Teddington, and elsewhere in connection with alloys containing various percentages of copper, tin, and zinc, etc., and also the effects of maturing and of heat treatment

One of the important points mentioned was the improvement that took place in alloy castings as they aged It was stated that castings which had a tensile strength of 10.8 tons per sq in when, say, a few days old, gave up to 13 7 tons per sq. in. when nine to twelve months had elapsed

As regards heat treatment, an alloy containing 4 per cent zinc was improved to a remarkable extent by annealing, the tensile strength being increased from 9.5 to 15 tons per sq in and the elongation from 10 per cent to 20 per cent.

Dr. Rosenhain set forth the great benefits gained from the use of aluminum pistons in internal combustion engines, owing to the high thermal conductivity in comparison with iron or steel, and also to the relatively light weights. He also pointed out that thermal conductivity was increased considerably by annealing

As regards the so-called "growth" of aluminum pistons in use, he stated in reply to a question that in his experience such a thing did not exist, provided pistons were properly annealed before fitting to the engine

Aluminum admittedly gave comparatively poor performances as regards tensile strengths at high temperatures, the figures falling from 13 5 tons at 50 deg C to 2 5 tons at 350 deg C. An alloy containing 12 per cent copper fell from 12 5 tons to 4 tons at the same temperature as above, while the addition of 1 per cent of manganese improved the performance considerably, the figures being 10 tons at 250 deg C

For the purpose of resistance to shocks such as those induced by the explosions in a petrol engine, an alloy containing 4 per cent copper, 2 per cent tin, and 1½ per cent zinc gave the best results

The lecturer next outlined the investigations carried out in regard to aluminum alloy cylinder blocks fitted with steel liners He pointed out that this system was essentially bad, owing to the effect of widely different expansion ratios, aluminum having a ratio of expansion two and a half times as great as that of steel

The work which had been accomplished in connection with the production of an all-metal airplane was also discussed. The lecturer exhibited samples of rolled sheets of aluminum which had been produced for this purpose, and pointed out that the weight of the metal for the covering for airplane wings, etc., was a third that of doped fabric, with twice the strength It was, however, not as yet suitable for war purposes, for, although non-inflammable, of course, it was extremely easy to tear, and in the event of large gashes caused by shrapnel the probability was that the wind would tear away large sections, but more or less clean holes, such as produced by rifle bullets, had remarkably little deleterious effect.

A slide was exhibited showing the wreck of a German all-metal airplane fitted with corrugated aluminum sheets on the wings

A large variety of aluminum alloy castings, both die cast and sand cast, were exhibited, and also portions of rigid airship and girder work.—*Automobile Engineer*

Adjustable Camber and Variable Angle of Incidence

By Thomas P. Leaman

The following is presented as merely a tentative discussion of the possibilities of adjustable camber and variable angle of incidence While the subject needs further investigation, it is thought that these remarks will arouse interest in the problem and possibly encourage aerodynamical investigation of the subject.

FIG. 1.

There are three points in which the above arrangements would be advantageous.—

1 The introduction of a deep cambered wing with attendant large lift values at high angles of incidence and low speed.

2. The obtaining of a low cambered wing with low lift and high efficiency at small angles and high speeds.

3 The maintenance of the propeller with its axis parallel to the line of flight whereby a greater efficiency is produced.

4 The decrease in parasite resistance at climbing and high angles by maintaining the minimum resistance position of the fuselage at all angles.

There is no doubt, for instance, as shown in Fig 1—the conventional fixed angle airplane in horizontal flight at a large angle of incidence—if the arrow S indicates the flight path while T represents the propeller shaft, that in this attitude the incoming air enters the propeller disc at an angle with a resulting direct loss in efficiency.

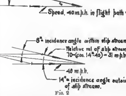


FIG. 2

There is also another possible disadvantage attaching to dimensional fixed angle airplane. In airplanes having a fixed incidence angle, that part of the wing acted on by the slip stream of the propeller, has, at different attitudes of the machine, (corresponding to different angles of incidence) a *smaller range* of incidence angle than that part of the wing beyond the action of the propeller disc The portion of the wing thus affected, may, in a small machine of the scout type, amount to one-fourth of the total wing span and this effect occurs at the center or most efficient part of the wing and where the air velocity is highest Furthermore, this difference is greatest at large angles of incidence where a high lift is most needed

To illustrate the above point, (See upper diagram, Fig. 2), we will assume an airplane in horizontal flight at a speed of 40 m.p h. angle of incidence of 14 deg. and with a slipstream velocity of 70 m.p h. The wing chord, for convenience, is set parallel to the propeller shaft.

The resultant slipstream is shown in the lower diagram (Fig. 2) and gives an actual angle of incidence of only 8 deg. within the slipstream, while the wings are in reality at an angle of 14 deg. with the line of flight. This means a net loss, in this

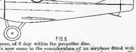


FIG. 3.

instance, of 6 deg within the propeller disc.

We now come to the consideration of an airplane fitted with adjustable camber and variable incidence angle wings. We will assume for the purpose of comparison, the same conditions of high incidence and low speed as heretofore.

Fig. 3 and Fig 4 show the side elevator of a purely hypothetical machine to illustrate the general characteristics of adjustable camber It will be noted that a proper variation of camber is approximated in a simple manner by hinging the wing throughout its length, about one-third to the rear of the leading edge, thus giving also a simultaneous change in incidence angle No method of lateral control is shown.

Disregarding the tapered form of wings and tail, which have no bearing on this discussion, the sketches show a machine of rather conventional design. The important points of difference are the adjustable camber feature and the shortening up of the fuselage, with necessarily larger tail surfaces than in current practice.

Comparing now the adjustable camber machine with that of conventional type, we arrive at the following conclusions.

(1) The line of propeller shaft and line of flight become co-incident for all angles of attack, with consequent added

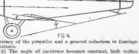


FIG 4

efficiency of the propeller and a general reduction in fuselage resistance.

(2) The angle of incidence becomes constant, both within and outside of the slipstream, at all angles of the wing chord with the flight path, so long as the propeller shaft remains parallel to the latter

In making a landing with this type of machine, the camber and incidence angle (relative to the line of propeller shaft) would be increased to a maximum of say 10 deg When the tail skid is in contact with the ground, the angle of attack increases to about 23 deg The airplane now cannot rise again, as *Ky* has exceeded the critical angle by several degrees. The *Kx* factor is also much greater than it is at the critical angle by several degrees. The *Kx* factor is also much greater than it is at the critical angle, thus the wings themselves become a powerful brake, causing the machine to come to a *quick stop after a landing is made.*

It would seem, if the above assumptions are correct, that the advancement of the adjustable camber airplane has been somewhat neglected, notwithstanding the many structural difficulties inherent in this type and the expense necessary for its full development.

The McCabe Sleeve

By I. E. McCabe

The McCabe Sleeve is a wire rope fastener applied by the use of mechanical means only and has been developed chiefly for use on aircraft. It is made up without the use of solder with attending dangers from acids, fluxes and overheating and has working tolerances not difficult for the workman to maintain. Its efficiency is both high and uniform when the simple directions for making up are followed and inspection is an easy matter.

The sleeve itself is a one-piece construction comprising two parallel tubes, one of which is extended beyond the other, the extended portion being known as the snub. It is formed of

Fig. 1
The Illustrations Show the McCabe Sleeve, the Thimble, Its Appearance Before Twisting, and the Finished Joint.

specially rolled sheet copper by automatic machinery, brazed between the tubes upon one side, thoroughly pickled to remove scale, and tinned to prevent corrosive action upon the cable and to secure a finish similar to galvanized or tinned cable. The finished product is inspected and gauged to insure against difficulty in insertion of the cable.

Fig. 1 illustrates the 3/32 in. sleeve and thimble both before and after application and Fig. 2 the tools used.

The first operation, in the making up of McCabe joints, requires tying the cable on each side of the place to be served about ⅜ in. away. This is accomplished by the use of two or three wraps of soft wire the ends of which are tightly twisted together. The operation is necessary to prevent unraveling of the cable and to bind the ends of the strands closely for easy insertion into the sleeve. The cable is then placed between cutters of pliers, shown in Fig. 2, and sheared.

The end of cable is first inserted into the short tube of sleeve at the snub end (see Fig. 1), the binding wire loosened slightly and the cable pushed through until it protrudes about ⅛ in. Care must be taken not to let it extend through too far or the strands will unravel. It is next threaded through the coil thimble (see Fig. 1), and from that, using the same methods to prevent unraveling, into the long tube up to the snub. The surplus cable, which has been pulled through the short tube to enable threading into the other, is now carefully pulled back and the coil thimble is kept to the center of the loop, during the operation, to prevent kinks or sharp bends in the cable which would lower the strength.

The joint is now ready to be twisted (see Fig. 1), and special pliers are applied, (see Fig. 2). Care must be taken that correct chambers in the jaws are used, that the parallel sides of the jaws face each other and that the edge of the jaws are parallel with the ends of double tubes of the sleeve at the central point between the tubes. The sleeve is then twisted one and one-fourth turns in such direction that the strands between the joints are twisted tighter. Twisting in the opposite direction tends to decrease the efficiency about 3 per cent.

It is essential that the twisting be done along the longitudinal axis of the sleeve. After the pliers are removed, the joint is held in one hand while the snub is grasped, not more than half way from the end, by the nose of the pliers, and bent over in such direction that the rib on the snub is outside. This bend should be nearly 120 deg. and the snub is completed by being placed between the portions of the jaws nearer the hinge of pliers and crimped down tight against the main body of the sleeve.

The joint is now complete (see Fig. 1), and the inspection consists of examining the end of the snub to see that the cable is in sight and that the snub is pressed down tight against the sleeve, it should also be noted that the sleeve is twisted properly, that is, in the right direction and along the longitudinal axis. Should, by any chance, the sleeve be faulty the defect will be shown by the surface of same.

The origin and development of this device began in the period when aviation was still in its infancy. The writer, while carrying on experimental work with gliders during 1911 and 1912, met with considerable difficulty in the use of piano wire, so he substituted cable and encountered further trouble in making up a satisfactory cable joint.

Having been previously employed in telephone work and being familiar with the wire joints in use in that field, he secured a number of standard sleeves supplied for that purpose.

Fig. 2
Tools Used in Forming the McCabe Sleeve

From these, by a number of experiments and tests made rather crudely on account of the limited apparatus at hand, he was able to evolve a type of joint which gave much better satisfaction than the several types he had previously used. The same was used in the form developed, during the following three years on two airplanes built by himself, and proved thoroughly dependable under severe usage.

The joint, as used at that time, was composed of a reduced length standard wire sleeve, twisted one and one-half turns. Instead of the snub as now used the cable itself was extended through the sleeve, bent back and tapped down with friction tape. This snubbing of the cable permitted a reduction in the number of turns from three and one-half to one and one-half thereby shortening the sleeve about 40 per cent, cutting down both the weight and head resistance.

The stranded ends of the cable, although taped, had a ten-

dency to become frequently exposed, causing much discomfort and oftentimes damage to the unfortunate who happened to come in contact with them. Later the idea of the snub, as now used, was originated to overcome this and, upon patents being issued, the matter was taken up with the Frank B. Cook Co. of Chicago which had manufactured most of the sleeves previously used.

This concern has been engaged in the manufacture of wire connectors and sleeves of various types for nearly twenty years and further development was undertaken at its factory.

A large selection of dies for various types and sizes of wire joints were available and, with the aid of these tools and considerable bench work, some 4,000 or more samples of McCabe Sleeves of various types, sizes, gauges, and materials were made and tested under varying conditions during 1916 and 1917 by the writer.

Weight is a factor and also the question of air resistance demands as small a joint as possible. Comparatively, the McCabe joint is called upon to stand from three to five times the tensile strain, is half the length and weighs less than the standard wire connector of the nearest diameter.

In the early tests, breaking of the cable was thought to be a sufficient evidence of strength, especially as the breaks usually occurred in the region of its rated strength. Later this was found to be a fallacy and thereafter, all tests were made comparative to test loops of cable from the same reel with both the socket and the served and soldered types of terminal.

As previously mentioned the experimental samples were partially hand formed and the consequent irregularities in them were found to be responsible for considerable variation in testing. From five to ten loops of each model of sleeve were usually tested at a time. The tools for twisting also have much bearing on this.

The knowledge of these facts necessitated the adoption of methods of manufacture which would not permit a sleeve to vary from close limits, and also the design of tools for the purpose of simplifying the operations in making up the joint and making certain the easy maintenance of limits that insure its efficiency.

There are several types of terminals which have high efficiency when made up properly, but many mechanics are unable to work within tolerances that insure this. The very nature of cable terminals, especially in the sizes most common to existing aircraft, is such that the tolerances must be necessarily small. In the McCabe joint these are maintained mainly in its manufacture and the user has far more latitude in applying it than is possible with most of the types now in use.

In developing tools for making up the joint consideration was given the suggestions of prospective users that a set of pliers, consisting of two pair, be made sufficient to perform all the necessary operations in all the seven sizes of sleeve which were being developed, that they might be made a part of the airplane's tool kit.

This required that the cutter for the cable be included in the tools and previous experience had shown that a distinct type of forging was required to give service. Also this same type of forging permits a lighter construction which is of moment if to be a part of the airplane's equipment.

The matter was taken up with Mathias Klein & Sons of Chicago, and with their cooperation various forms were made and tried out, leading to the design of tools shown in Fig. 2 which have been adopted with slight modifications in the shape of the handles.

A set of Klein's Aero pliers, as now supplied, is sufficient for making up all sizes of joints now made, with possibly the aid of a small pair of lineman's pliers to be used in cutting the coil spring for thimbles and for tying the cable. A form of bench tool, which is very convenient where a vise is at hand, has been developed to substitute for one pair of pliers. Its use saves considerable time as the sleeve may be held in it while the cable is inserted, allowing both hands for this operation as well as for the twisting. A single movement of the handle down closes and locks the jaws upon the sleeve and a movement opposite releases. The handle of the plier is supplied with a locking device of the familiar link type not so rapid in operation but still satisfactory.

Another problem, given a careful investigation, was the prevention of corrosion within the joint itself. The chemist engaged in this investigation found the previous experience of the Frank B. Cook Co. in its own wire joint to be the most satisfactory and therefore dependable as the conditions are similar and also more favorable for the McCabe sleeve in its field.

While the investigation was being conducted, inquiries were made among a number of customers in the telephone field who had been using the wire sleeves for a number of years. These were made for the purpose of securing a number of joints which had been in use over a period of years, that their condition might be observed. Some samples were received which were stated to have withstood ten years' service and the condition of the wire to which it was attached indicated this. In spite of the fact that the wire outside the sleeve had rusted nearly through, the wire inside was found intact with the galvanizing upon it. As corrosion within the joint would interfere with the conductivity of the line, their use upon the telephone lines today in uncounted numbers after years of service, completely justifies the adoption of the same methods to guard against it in the McCabe sleeve. As a matter of fact chances are more remote for corrosion in the McCabe Sleeve than in soldered types of terminals, especially if acid has been used in the process of soldering.

Considerable criticism of the wire thimble, based upon a similar type used in the served and soldered terminal and since displaced by the type now used, has been offered. Instead of a soft wire, however, a tempered and plated wire is used, withstanding far more wear and tear, conditions which the soft wire failed to meet. The combination with the sleeve presents a neat appearance and its use aids materially in simplifying the operation of threading the cable through the sleeve. Comparative tests with other standard forms of thimbles show no appreciable difference in the sizes up to and including ⅛ in., delivering approximately 100 per cent efficiency. A slight drop in the efficiency is found in the two largest sizes and changes are being made to overcome the deficiency.

Under Table I will be found data on the several sizes now developed. The limits to the cable diameters are given as well as the rated strength. Also, under the head of maximum load, figures are given which are the highest that have been secured in the tests made and are not to be considered as the general performance of the cable. Although generally exceeded in tests the rated strength of the cable is the most reliable basis to work from. Their purpose here is to indicate rather the capacity of the McCabe joint. The table of weights are for the sleeve only and the lengths of the sleeve after it is twisted. The length of the double tube portion before twisting is approximately the same as the joint after twisting.

Table II is a report of a test in 3/32 in. cable made for the purpose of securing data regarding elongation of the McCabe sleeve as compared with the served and soldered and the open socket type of joint. This was made at the Robert W. Hunt and Co.'s laboratory in Chicago on a 50,000 lb. capacity Riehle testing machine. The head had a minimum velocity of ½ in. per min. The nature of the tests are such that a smaller machine with a lower velocity is preferable but at the time it was not available.

It will be noticed that the McCabe joint has greater elongation than the other two types, especially up to the elastic limit of the cable, which was found to be approximately 75 per cent of the breaking strain from comparative elongations taken from the first loop tested. The nineteen strand cable has (see Roebling's Report in the First Annual Report of the Advisory Committee for Aeronautics) approximately one and one-third times as much elasticity as a solid wire of the same material. This additional elasticity is the main reason for its use in place of solid wire. Sudden strains do not create the same tension, because, during the additional movement allowed, a portion of the energy is absorbed, thereby reducing the maximum to be withstood. Vibrations of the same amplitude do not put so high a strain on the cable as the wire thus reducing fatigue and crystallization.

The McCabe joint offers the user the added advantage of still greater elasticity which permits tuning the guys to the tension desired to maintain the machine in alignment and still allows a reserve movement to absorb shock and vibration.

Not being soldered, the temper of the cable is not affected in any way and there is no chance for vibration to localize, as sometimes occurs with cables which have been soldered at the

joint or socket, and which produces in time the inevitable crystallization and failure at a point not far from the soldered portion. Further, the strands, being separate, have a better chance to equalize, preventing undue loads on only a portion of the strands which occurs if they are of unequal length. The additional elasticity of the joint itself is another feature which assists in the even distribution of load and produces the uniform efficiency secured.

The writer contemplates, in the not too distant future, undertaking tests that will indicate comparative performances under combined stress and vibration over periods of various lengths. Data of this nature will be more indicative of trustworthy performance than the mere tensile tests now used. Apparatus of a peculiar nature and differing from that now existing in order to create the conditions desired, must be designed and built. This involves more time, study and expense than the writer can devote to it at this time but any information or suggestions he may have are at the disposal of parties who wish to construct such apparatus.

From the directions given for setting up the joints the reader can easily infer that it does not require much time. Nor does it require long to become proficient for, after making up half a dozen joints, the user is generally able to proceed with full confidence that his work will be up to standard. In most cases the first joints made by many users have shown high efficiency under test.

During the demonstration of the device at the First Pan American Exposition, the writer made up something like 1,500 joints at the booth and the majority of these were tested with apparatus at hand to show the strength of the joint. The tests of these loops, which were made in 3/32 in. nineteen strand cable, indicated breaking strains from 1275 lb. minimum to 1325 lb. maximum, the cable breaking at all times. While being timed, the writer made complete test loops, 15 in. long, in 60 sec., or 30 sec. a joint. Full equipment was at hand and arranged conveniently as would be in the shop, the bench clamp being used in this case. Fifty seconds per joint was required when the pliers alone were used. This performance of course would in general practise be the exception rather than the rule, but if the time is trebled it is still very rapid.

The time required increases with the larger sizes, from 4 to 8 minutes being necessary for the 3/16 in. joint. In the larger sizes the time is governed more by the strength of the user and in the smaller by the nimbleness of his fingers. This can be controlled in manufacture by the selection of workmen having the desired attributes and by progressive assembling by several if in sufficient quantity. Although a longer time is necessary on the field it is still less than required by present methods and the repairs will be of a permanent nature and accomplished without risk of fire.

TABLE I

Size of sleeve	Diameter of cable (in.)		Rated strength of 19-strand cable	Maximum breaking strain secured	Weight of sleeve	Length of finished joint
(in.)	Min	Max	(lb.)		oz. av	(in.)
1/16	0625	0687	500	680	15	1 5/8
5/64	0782	886	750	828	.25	1 6/4
3/32	0936	1032	1100	1575	65	1 7/8
7/64	1094	1202	1600	1660	60	5 1/4
1/8	125	1375	2100	2560	87	5 7/16
5/32	1562	1718	3200	4060	1.36	5 1/2
3/16	1875	2066	4600	6266	1 66	6 1/2

These tests indicate the highest breaking strains attained up to this time. The average is usually above the rated strength but not to the extent here shown.

The 3/32 in. 19-strand Roebling cable, measuring .094 in. to .095 in. was used in tests. Loops No. 1 to 10, inclusive, and No. 13 were made up with standard McCabe sleeves. No. 11 is a served and soldered type made according to Army specifications and No. 12 is an open socket type.

TABLE II

	Length at 150 lb tension	Elongation (in.) only at			Breaking	Cable broke
No.	(in.)	650 lb	100 lb.	670 lb.	point	at (lb.)
1	28 75	26	11	.47	1 88	1330
2	28 70	26	16	64	1 96	1290
3	60 00	.28	20	54	1 85	1350
4	28 75	27	18	.54	1 65	1630
5	28 75	60	16	.58	1 65	1350
6	30 50	28	16	.56	1 95	1300
7	28 76	26	15	54	1 66	1235
8	28 75	-61	16	58	2 00	1290
9	30 00	30	16	65	1 88	1350
10	60 00	26	15	54	1.88	1350
11	28 75	26	10	66	2 90	1350
12	30 12	—	—	—	1.75	1316
13	28 80	26	.66	64	76	1165

* Test loop No. 13 had McCabe joints which had been subjected to a load of 1,000 lb for sixteen hours to ascertain effect. This loop was used to ascertain the elastic limit and breaking strain of cable as basis to secure loads at which elongation was measured.

reached with a comparatively rich mixture. The maximum torque having been attained, observations of torque were continued while the rate of gasoline supply was gradually reduced. The mixture was made leaner until the torque fell off considerably, and then gradually enriched just enough to regain the maximum torque which had previously been noted. Readings were then taken of the various temperatures, pressures, torque, rates of flow and speed. The fuel supply from the X tank was then cut off and hecter supplied to the carburetor. After adjusting the carburetor for maximum torque with the least expenditure of fuel as described for X gasoline, readings of test data again were made. By changing from one fuel to another in this manner, it is possible to eliminate

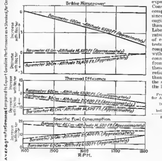


Fig 2

One gallon of hecter contains nearly 9 per cent more heat units than the same quantity of X gasoline, and the brake thermal efficiency of the engine using hecter is about the same percentage less than when using X gasoline. Thus the same tank full of either fuel would supply a plane with about the same available energy. Any part of a flight at very low altitude might be accomplished at a slightly lower plane speed with the hecter than with gasoline, as a consequence of the power characteristics described above.

It has been claimed that a high-compression engine has a greater factor of safety when operated with hecter fuel than with gasoline. The engine was not operated for a sufficient period of time to ascertain whether engine deterioration was more rapid with the 7.2 compression ratio than would be expected from experience with the 5.6 compression ratio. Consequently no comparison can be made of the effect of compression on fuels upon engine deterioration. However, since it is not generally considered advisable to operate an engine of this type with gasoline at a higher compression ratio than 5.6, it is of interest to compare the performance of a Liberty twelve-cylinder aviation engine of 5.6 compression ratio using gasoline, with the performance of the same type of engine with 7.2 compression ratio using hecter. Previous tests with this type of engine have shown that this change in compression produces about 10 per cent increase in power, with about the same percentage decrease in weight of fuel consumed per unit power. This change would be expected from a comparison of the "air standard" efficiencies. From these data it is concluded that hecter in a 7.2 compression ratio engine would produce about 10 per cent more power than would X gasoline in a 5.6 compression ratio, while using the same weight of fuel per unit power as for X gasoline in the lower compression.

From an abstract of Report No. 86 of the National Advisory Committee for Aeronautics, Washington.

Distillation Initial boiling point	Hecter Fuel Temperature deg cent	deg fahr	X Gasoline deg cent	deg fahr
Per cent	76	169	59	138
10	77	171	72	162
20	77	171	77	168
30	77	171	82	180
40	78	172	87	116
50	78	172	92	198
60	78	172	97	207
70	78	172	103	217
80	78	172	111	232
90	78	172	127	261
95	79	174	150	302
Dry point*	82	180	151	307

* 99 per cent distillation for Hecter and 96 per cent for Gasoline

Hecter Fuel Compared with Export Aviation Gasoline

Aviation engine developments for attaining higher power at altitude are following two principal lines, supercharging and an increase in the compression ratio. For the latter, fuels have been demanded which are capable of operating under compressions too high for gasoline. The Bureau of Mines in a comprehensive investigation of fuels for internal combustion engines, found cyclohexane mixtures to possess properties which led them to develop the hecter fuel. The ability of this fuel to withstand high compression without knock was demonstrated in an experimental engine at ground level and its general usability was proved by actual flight tests. It was accordingly submitted to the Bureau of Standards for comparison with export aviation gasoline as to power producing ability and fuel consumption when used in an engine with a 7.2 compression ratio.

The gasoline used in the tests was the standard reference fuel of the Bureau of Standards, known as X gasoline. It complies with specification No. 3512 of the Bureau of Aircraft Production for export aviation gasoline for the use of the A. E. F. 1918. The hecter fuel supplied for the tests was a mixture of approximately 30 per cent benzol and 70 per cent cyclohexane by volume. The properties of both fuels are shown in Fig 1 and the accompanying table.

The fuels were tested in a twelve-cylinder Liberty airplane engine equipped with special pistons giving a compression ratio of 7.2. This ratio gave a measured compression pressure of 170 lb. per sq in gage. The engine was mounted in the altitude chamber of the Bureau of Standards automotive powerplants laboratory where controlled conditions of air

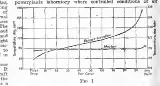


Fig 1

pressure and temperature approximate those prevailing at altitudes up to 30,000 ft.

In these tests two fuel tanks were used, one containing the X gasoline, the other hecter. The engine was started on X gasoline and the desired conditions of speed and altitude

effectually from the comparison of the fuels any effects due to changes in the condition of the engine.

The test results are shown graphically in Fig 2, which is a performance comparison on a percentage basis, all results being plotted against altitude.

For flight at low altitudes hecter fuel showed slight advantages in comparison with gasoline by affording a small increase of power over that necessary to offset the disadvantage of increased fuel consumption. The usual ratio of fuel weight to plane weight is of the order of 1 to 7, so that for full-throttle flying an increased fuel consumption of 7 per cent balances an increase of 1 per cent in power developed. The test at 6500 ft altitude showed that hecter fuel developed slightly more power than X gasoline, the maximum advantage being 7 per cent and the average for all speeds 4 per cent, whereas the increase in fuel consumption averaged 5 or 6 per cent. Since at 14,000 ft. and 25,000 ft. no appreciable difference in power was obtained, whereas the fuel consumption of hecter was greater to the extent of 15 per cent by weight, the advantage lies with X gasoline.

The large difference in densities of hecter fuel and X gasoline makes the fuel comparisons by weight and by volume read differently, and care must be exercised to distinguish them. Upon reckoning pounds per brake-horsepower-hour to pints per brake-horsepower-hour it is found that hecter consumption at ground is less by volume than and about equal to that of X gasoline at 25,000 ft.

Laddon Ground Attack Planes Ordered

Ten Laddon ground attack airplanes will be built for the Army Air Service under a contract just awarded the Boeing Airplane Co., of Seattle, Wash. The first delivery is scheduled in November, with other machines to follow before the end of the year.

These machines belong to the G. H. X. type, which was developed from the designs of I. M. Laddon, Supervisor of Design Group No. 2, at the Engineering Division of the Air Service, McCook Field. In the spring of 1918 Mr. Laddon was selected to assist Capt. Georges Lepere, who was engineer in charge of the French mission at Detroit. In this capacity Mr. Laddon assisted in the design of such airplanes as the Lepere Biplane and the Lepere Triplane, and it was his connection with this work that led to the erroneous report, reproduced in our issue of June 15, 1920, that the G. H. X. airplane had been designed by Captain Lepere.

The Laddon or G. H. X. ground attack airplane has a span of 67 ft. and weighs, empty, about 3½ tons, 1 ton of which is represented by armor plating ¼ in. thick. The power plant consists of two 400 hp Liberty Twelve engines. The armament includes a 37-mm. rapid fire gun mounted in front, four machine guns trained to fire through the floor, two machine guns at the rear and two above the wings.

CLASSIFIED ADVERTISING

10 Cents a word, minimum charge $2.00, payable in advance. Address replies to box numbers, care AVIATION AND AERONAUTICAL ENGINEERING, 22 East 17th Street, New York.

FOR SALE—One brand new and two slightly used American Curtiss ships all linen covered and in beautiful condition. If you want a ship cheap come and get one of these at your own price. Write or see Billy Parker, Dewey, Okla.

HAMILTON PROPELLERS

Hamilton Aero Mfg. Co., 679 Layton Blvd. Milwaukee, Wis.

Grand Rapids Vapor Kilns

are used by these aircraft concerns with absolute satisfaction.

Standard Aircraft Corporation
Fisher Body Corporation
American Propeller & Mfg. Co.
Alexandria Aircraft Corp.
Gallaudet Aircraft Corp.
Thomas-Morse Aircraft Corp.

Submit your drying problem to experts who make a specialty of kiln design and are prepared to furnish and install all equipment and instruments.

GRAND RAPIDS VENEER WORKS
Grand Rapids, Michigan Seattle, Washington

HALL-SCOTT

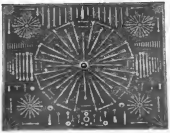
TYPE L-6
AIRPLANE ENGINES

Hall-Scott Motor Car Company
West Berkeley, California

Warwick **NON-TEAR** *Aero-Cloth*

A SAFE CLOTH *for* FLYING

For Particulars Apply to
WELLINGTON SEARS & CO.
66 Worth Street, New York



The pioneer manufacture of airplane parts made from bar stock. Any and everything pertaining to the manufacture of airplanes.

Any Quantity

A. J. MEYER MANUFACTURING CO.
819 John Street West Hoboken, N. J.

Flottorp Manufacturing Co.

AIRCRAFT PROPELLERS
Established 1912

213 Lyon St., Grand Rapids, Michigan

Contractors to United States Government

AIRPLANE INSURANCE

FOR THE

Manufacturer—Flyer

Fire—Collision—Damage to Property of Others
Legal Liability—Life—Personal Accident
Conservative Rates—Best Companies

PHONE—WRITE—WIRE

HARRY M. SIMON
Insurance Expert
81-83 Fulton St. New York, N. Y.